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JUN 26 1951

VOL. XII, No. 5 MAY, 1951

BORDEN'S REVIEW

of

NUTRITION RESEARCH

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BORDEN'S REVIEW
of
NUTRITION RESEARCH

Reviews and summaries of research information concerning nutrition and foods. Published monthly, except July and August, by THE BORDEN COMPANY; officers of the Company: Theodore G. Montague, president; E. L. Noetzel, treasurer; T. D. Waibel, secretary. Editorial office: 350 Madison Avenue, New York 17, N. Y.

NUTRITION IN PREGNANCY

By RUTH WOODS

The belief that the pregnant woman should eat more and better foods during the gestation period is a time-honored concept held by both layman and scientist alike. It is only within the last decade or so, however, that controlled, large-scale clinical studies have been conducted to evaluate this concept from a scientific point of view. The evidence gathered from these studies has indicated at least three things: The diet of the woman during pregnancy has a significant effect upon her general health and nutritional status; it may also bear an important relation to the entire course of the pregnancy, influencing to some extent the development of toxemia and other complications of pregnancy; and, finally, nutrition in the pre-natal period may have a profound effect on the growth and development of the fetus and on the condition of the infant at birth, as well as thereafter. This last is a particularly outstanding finding because it has demonstrated that the old idea of the fetus being a complete parasite and deriving all of its nutritional requirements at the expense of the mother is no longer strictly true. It has been suggested by both animal experiments and clinical studies that the mother's reserve stores of nutrients do not always protect the developing fetus from deficiencies in the maternal diet during pregnancy. During the course of his studies on the effect of maternal malnutrition on the incidence of congenital deformities (1), Warkany (2) was led to propose the following concept of the maternal-fetal nutrition relationship:

> "The stores of the maternal tissues act as 'buffers' which prevent deprivation of the developing embryo as long as possible. In fact it was assumed until recently that these maternal stores either protect the offspring completely, thus resulting in the delivery of normal young, or that in the case of extreme dietary deficiency the embryos die *in utero*. Although there is some truth in this 'all or none theory' it is not entirely correct. Between these two extremes there exists a narrow range in which maternal nutritional deficiency may result in arrest of the embryo's development without causing death. In this case, congenitally deformed offspring may be the result."

The overall conclusions in the majority of recent studies on prenatal nutrition have indicated a markedly lowered incidence of stillbirths, premature births and early neonatal deaths with improved maternal nutrition. As Burke (3) has pointed out, greater attention to the nutrition of the pregnant mother should result not only in healthier babies with fewer physical handicaps, but also in lowered maternal morbidity and mortality, due

to the better health of the mother during pregnancy and to the lessened incidence of complications, especially toxemia.

Early Studies:

The first large scale report on the relation of diet to the nature and outcome of pregnancy to receive widespread public attention was a series of studies conducted in Canada by Ebbs, Tisdall and coworkers (4, 5, 6) and first published in 1941. These, as well as most of the other early investigations, were reported in considerable detail some seven years ago in this publication (8) and will be reviewed here only briefly.

Canadian Studies: Ebbs, Tisdall and associates (4, 5, 6) studied a group of 120 women of low income on poor diets during the last half of pregnancy. As controls they selected 90 other women from the same income level and on equally poor diets who were supplied with supplementary rations of milk, cheese, oranges, tomatoes, wheat germ and Vitamin D capsules, as well as 170 women with fairly adequate incomes who were instructed in the type of diet considered desirable for pregnancy.

The incidence of miscarriages, stillbirths and deaths in early infancy was significantly lower in the groups on supplemented and good diets, and these women also enjoyed better health throughout pregnancy, had fewer complications and proved to be better obstetrical risks than those left on poor diets. There was also a marked increase in the incidence of minor and major diseases in the infants born of mothers in the poor diet group. In a large proportion of the cases, it was possible to tell the diet group of the mother by the appearance of her baby at six months of age.

British Studies: In Great Britain, the People's League of Health (7) investigated the effect of maternal nutrition on maternal and infant morbidity and mortality in more than 5,000 pregnant women. Supplementary vitamins and minerals were given to one-half of the women studied. Statistical evaluation of the results showed a definite reduction in the incidence of toxemia (about 30%) among the women receiving nutrition supplements, as well as a noticeable reduction in the number of premature births as compared to the control group on non-supplemented diets.

Additional studies by Balfour *et al* (9) were reported in 1944. More than eleven thousand women attending prenatal clinics in impoverished areas were selected for supplementary feeding, while the records of some eight thousand women attending the same clinics, but who did not receive supplements, served as controls.

The supplemented groups received every two weeks a pound and a half of powdered milk and either four ounces of a special yeast extract (provid-

ing, among other factors, 240 I.U. thiamine daily), or eight ounces of a proprietary preparation supplying liberal amounts of vitamins A and D, phosphorus, calcium and iron. Both supplemented and control groups received some milk distributed by the local health authorities.

The treated groups fared better in all cases. Those receiving the proprietary preparation in addition to the powdered milk exhibited a slightly lower rate of stillbirths and neonatal deaths than the controls. The groups receiving the yeast supplement, in addition to the powdered milk, however, exhibited a marked reduction in rate of stillbirths and neonatal mortality. The effects of the yeast supplement were greatest in the localities where the control mortality rates were highest.

United States: Most of the early studies both in the United States and abroad were concerned with the importance to the mother of adequate nutrition during the prenatal period. Later studies began to indicate the fact that prenatal nutrition may also have a very pronounced effect on the condition of the infant. As was indicated by the British studies, poor maternal diets had a direct influence on infant mortality, particularly by predisposing to prematurity. Other studies, chiefly in the United States, revealed further that actual damage to the fetus may result from dietary deficiencies of the mother, resulting in the birth of defective infants (11, 12, 13, 14).

Of the many clinical studies conducted in the United States (8) perhaps of most interest have been those of Burke, Stuart *et al* (15, 16) at the Harvard School of Public Health's Department of Maternal and Child Health. They observed over 200 women and their infants. The diets of the mothers during the prenatal period were checked and rated according to values recommended by the National Research Council, as "excellent," "good," "fair," "poor" or gradations thereof. The infants were rated at birth and during the first two weeks of life on the basis of weight, length, appearance, health, progress, etc. These ratings were then correlated with the ratings of the mothers' prenatal diets. It was concluded that:

1. If the diet of the mother during pregnancy is poor to very poor, she will undoubtedly have an infant whose physical condition will be poor. In all the cases considered, all stillborn infants, all infants who died within a few days of birth—except one—most infants who had marked congenital defects, all premature and all functionally immature infants were born to mothers whose diets were very inadequate.
2. If the mother's diet during pregnancy is good or excellent, her infant will in all probability be in good or excellent condition. It may, however, happen rarely that a mother whose diet during pregnancy is good or excellent will give birth to an infant in poor physical condition (1 out of 216 cases in this study).

These early studies emphasized the importance of good prenatal diets both with respect to the health of the mother and the condition of the infant, not only at birth, but subsequently as well. They also revealed that the diet of a majority of expectant mothers falls far short of meeting desirable nutrition goals during this critical period and emphasized the fact that an adequate diet in pregnancy is an important public health measure demanding more general professional and official recognition. (3)

Recent Studies:

With few exceptions, most of the early studies on nutrition during pregnancy have been strongly suggestive of a positive correlation between improved maternal nutrition and improved health of both mother and newborn child. It is important to recognize, however, as Smith (17) has pointed out that certain aspects of the evidence thus gathered may not stand up too well upon critical analysis. *The great difficulty,* he states, *is to construct experimental situations producing incontrovertible proof that undesirable results of human pregnancy, either maternal or fetal, are direct consequences of maternal dietary factors.* The difficulty lies in the fact that women who eat poor diets may well be suboptimal persons in many other ways as well, as in heredity, environment and past history of disease. Thus, it is difficult to determine—especially in such women—whether the condition of the infant is the result *only* of the mother's diet. Smith adds, further, that if maternal malnutrition cannot be shown to be the sole cause of fetal subnormality, it would be helpful to determine at least the relative degree of its influence. (4)

Experimental Approaches: At least four types of experimental approaches can be made toward a clearer understanding of this problem:

(1) The calculated restriction of maternal intake during pregnancy.

This, of course, is suitable only for animal investigation and has been achieved in the classic investigations of Warkany (1, 2). In this type of experiment, however, the diet is extremely limited and the maternal animal must be treated and fed with extreme care, lest she fail to produce any offspring at all. By means of such studies, however, Warkany has conclusively shown that controlled deficiences of certain nutrients in the mother's diet can and do lead to predictable malformations and abnormalities in the young.

(2) Comparison of accurate analyses of voluntarily consumed diets of pregnant women with maternal nutritional status and with the outcome of pregnancy.

This approach has been exemplified by the investigations of Burke *et al* (3, 15, 16, 18, 19, 20). The results have been highly indicative of a relation between maternal diet and the outcome of pregnancy, but as Smith has pointed

out, it is difficult to eliminate the possibility of other unfavorable conditions being present along with improper food habits.

(3) The calculated improvement of maternal diets during pregnancy in a selected experimental group evaluated in comparison with a comparable control group whose diets are not nutritionally supplemented.

The goal in this type of experiment is to have the two groups exactly comparable in all respects except the nutritional. This type of study is represented by the investigations of Ebbs *et al* (4, 5, 6) and the British studies (7, 9). Here again, the evidence has been strongly suggestive of the relation between improved maternal diets and the reduced incidence of miscarriage, toxemia, prematurity, stillbirth and neonatal death.

(4) Observing the effects of widespread nutritional inadequacy due to war or other calamity affecting an entire populace.

This type of experiment, as Smith points out, takes advantage of a period of starvation as an unfortunate, but nevertheless potentially useful, human experiment closely resembling the more controlled type of animal experiments described in the first approach. Controls are supplied by statistics taken from pre- and post-starvation periods.

Effect of Mass Starvation on the Outcome of Pregnancy: During the last war conditions became such that it was possible to conduct investigations on nutrition and pregnancy along the lines indicated in the fourth type of experimental approach. The observations of Smith (17, 21) in Holland and of Antonov (22) in Leningrad will be described in illustration of the findings made available through this type of inquiry.

(Holland): From September, 1944, until the liberation of Holland in May 1945 the Dutch government initiated a general transportation strike in northwestern Holland against the Nazis. During this period little or no food was transported into the major cities. Roads and canals approaching the cities were carefully guarded by the enemy so that little food or other supplies could be smuggled in. Under these circumstances it was possible for country dwellers to live fairly well, while the city populations—only a few miles away—were literally starving. At one point, food values reached a low of about 1145 calories (RDA*, 2500 calories) and of 34 grams of protein (RDA*, 85 grams) per day for expectant mothers.

Very soon after the liberation, Dr. Sinclair, director of Oxford Nutrition Survey for SHAEF, made an attempt to evaluate as precisely as possible the nutrients actually available to pregnant women in certain areas. His results are shown in Table I.

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*Recommended daily allowance, U. S. Food & Nutrition Board

TABLE I. Nutrition Available for Pregnant Women (The Hague and Leiden)

Item	Recommended Daily Allowance (U.S. Food & Nutr. Board)	September 1944	February 1945	April 1945
Calories	2500	1925	731	912
Grams protein (vegetable)	85	38	24	28
(animal)		23	9	11
Grams fat	—	50	11	14
Mg. calcium	1500	1075	649	517
Mg. iron	15.0	16.3	9.6	10.7
I.U. Vitamin A	6000*	1260	445	766
Mg. thiamine	1.8	1.1	1	0.6
Mg. niacin	18.0	9.2	3.0	4.1
Mg. riboflavin	2.5	1.2	0.5	0.5
Mg. ascorbic acid	100	59	34	53

*⅔ carotene; ⅓ vitamin A.

Conditions in Holland, as summarized by Smith (17):

(1) Generalized undernutrition, rather than selective malnutrition. Total calories were about as depressed as were individual nutrients.

(2) The period of severe undernutrition was brief — particularly as related to the length of the gestation period.

(3) The populace had been fairly well fed prior to the hunger period.

(4) Rationing attempted to meet the requirements of pregnant women, but the intake still fell far short, in most respects, of the recommended daily allowances of the Food & Nutrition Board of the National Research Council.

(5) Relief was general, fairly adequate and very abrupt.

These facts indicate that in several basic respects the subjects of the investigation in Holland differed markedly from those studied by British and American workers. Notably, in the latter, the subjects are usually women who have eaten inadequate diets nearly all their adult lives and in whose diets a few specific nutrients are usually lacking while the total caloric intake is usually more or less sufficient.

In addition to analyses of the available foods and nutrients, the mothers and infants were closely studied during this period of generalized starvation in Holland. The findings indicated that about 50% of the women became amenorrheic and consequently infertile. The birth weights of the infants decreased, and rose after restoration of food, in a manner indicating that

fetal weight gain is particularly related to the maternal diet of the last half or trimester of pregnancy. Birth length was also decreased, but to a lesser degree than weight. The data was not considered of sufficient statistical significance to draw any conclusions as to the effects of undernutrition on abortion, prematurity, stillbirths, and neonatal mortality.

Smith concludes that the duration of maternal nutrition deficiency — long-term malnutrition as contrasted with brief periods of actual starvation — may be an important factor in determining whether or not the maternal nutritional status will influence the developing fetus; he also stresses the need for more precise knowledge as to the role of specific nutrient deficiencies as contrasted to overall, general undernutrition, particularly of total calories. The occurrences in Holland, however, Smith emphasizes, add support to the accumulating evidence from animal experiments and human nutrition studies, that fetal growth may be retarded by lack of proper maternal diet.

(Leningrad): Antonov (22) has described the severe hardships, physical deprivations and starvation experienced by the populace during the siege of Leningrad from 1941 to 1943. His studies were concerned chiefly with the condition of infants born during this period — particularly during 1942.

The principal available food was bread of poor nutritional quality (½ "defective" rye flour; ½ substitutes such as cellulose, malt and bran). The daily ration for manual workers averaged about 10-13 ounces; for sedentary workers, about 7 ounces.

Antonov reports that during the most severe period of hunger, the stillbirth rate rose to 56%, twice the normal rate, and that prematurity reached an unusually high rate of more than 40%. Birth weights were less than normal; physiological weight loss in the first few post-natal days was greater and of longer duration than normal; infant morbidity and mortality were high. It was concluded that severe quantitative and qualitative hunger of the mother decidedly affects the development of the fetus and the vitality of the newborn child.

Effect of Improved Maternal Diet on Maternal and Child Health: Approaching the problem from the viewpoint outlined under (3) on page , as was done in the early British and Canadian studies gives, as might well be expected, another picture of the role maternal nutrition plays in affecting the health of both mother and child. Since studies of this type more nearly approach normal conditions than do observations made during extreme starvation, the findings may be of more practical significance in determining the consequences of maternal diet during the pre-natal period. Among the more recent studies of this type are the very interesting experiences at the Experi-

mental Health Station in Oslo, Norway, which were conducted over a six-year period ending in 1944, by Dr. K. R. Toverud (23, 24).

(Dietary Regime). Mothers attended the Health Station at regular periods during pregnancy and were given complete health care and supervision as well as health and diet advice. The recommended food intakes per day were:

Protein	1 to 1½ gm. per kilo. of body weight
Calcium	1.5 gm.
Phosphorus	2.0 gm.
Iron	20.0 mg.
Vitamin A	at least 7000
Vitamin D	10 mg./day during last 2-3 weeks of pregnancy
Thiamine	at least 700
Ascorbic Acid	4 mg.
Vitamin K	75 mg.

To meet the protein need, the women relied chiefly on milk (¾ to 1 liter per day), occasional eggs when obtainable, and fish (largely salted and dried). Because of the war, meat protein was very scarce. It was calculated that the diet provided the required amount of calcium and phosphorus, but iron had to be supplied as supplementary salts. One tablespoon per day of cod liver oil provided vitamins A and D, and synthetic ascorbic acid was given to supplement the meager imports of citrus fruits. Although liberal amounts of potatoes and 95% extraction flour were used, additional thiamine was required and was supplied in synthetic form or in brewer's yeast. Vitamin K from green vegetables was too low to prevent prolonged clotting time of the newborn and 10 mg. per day were given routinely in the last few weeks of pregnancy.

(Maternal Findings). Anemia was reduced from 23% to 6%; even during the worst years of the war it was kept to a low incidence of 8-11%. Mild signs of thiamine deficiency were quite common — as evidenced by absence of thiamine in the urine, leg cramps, neuralgic pains, numbness of fingers and toes — these disappeared with the use of brewer's yeast. Edema which was very high among adults in Norway during the war — particularly because of the low intake of animal protein — remained fairly common, but no cases of eclampsia occurred among pregnant women attending the health station throughout their pregnancy.

(Infant Findings). Stillbirths were reduced by 50% in comparison to records for the rest of the city. Similar reductions occurred in neonatal and

total infant mortality; the prematurity rate was reduced and birth hemorrhages and rickets were completely eliminated.

Follow-Up Studies on Relation of Self-Selected Maternal Diets to Infant Health: The studies of Burke *et al* (19) conducted some eight years ago on the correlation between customarily consumed mother's diets and the condition of the infant at birth have been extended, in recent years, to include a further correlation between the diets of these same mothers and the condition of subsequent babies born to them.

Fifty-seven of the original 216 women studied were selected.* Careful records of their average diets during the latter part of current pregnancy were obtained and rated, as previously, "excellent," "good," "fair" or "poor." The condition of the newly-born babies was then rated and correlated with the rating of the mothers' diets. The data thus acquired was then compared with the findings in the previous experiment (six years prior).

They found, in the 284 cases studied**:

1. When the maternal diet was "excellent" or "good"—95% of the infants were in good or excellent physical condition. Only 5% were fair or poor. When the maternal diet was "poor", 65% of the infants were poor, 27% fair and only 8% in good or excellent condition.
2. Average birth weights and lengths of infants decreased as the maternal dietary rating became poorer.
3. Data were obtained on 53 matched pairs of siblings. Improvement of the infant's condition with improvement of the maternal diet and deterioration of the infant's condition with deterioration of the maternal diet appeared in this series where each of the 53 mothers was observed through two pregnancies. While the changes were not statistically significant, it was felt that this unique type of experiment (using each mother as her own control) was of special value in that it helped to minimize hereditary and environmental variables which influence the condition of the infant at birth, and to make possible a more nearly accurate estimate of the effect of nutrition alone.

Recommended Nutritional Allowances During Pregnancy:

The Food and Nutrition Board of the National Research Council has recommended the following daily intake of nutrients for normal, pregnant and lactating women as indicated in Table II.

Burke and Stuart (25) point out that "while many persons consider these allowances to be liberal, it should be remembered that they were designed to serve as guides and that they include a margin of safety over the minimum

*The number of babies born totaled 68.
**This included the original 216 babies, plus 57 second siblings, 10 third siblings, and 1 fourth sibling (total new cases, 68).

TABLE II. Recommended Daily Nutritional Allowances, Normal Woman, Pregnancy and Lactation

(Food and Nutrition Board, National Research Council)

Nutritional Essentials	Normal	Pregnancy (4th Through 9th Month)	Lactation
Calories*	2,100	2,500	3,000
Protein (Gm.)	60	85	100
Calcium (Gm.)	0.8	1.5	2.0
Iron (mg.)	12	15	15
Vitamin A, I. U.†	5,000	6,000	8,000
Ascorbic Acid (mg.)	70	100	150
Thiamine (mg.)	1.1	1.8	2.0
Riboflavin (mg.)	1.5	2.5	3.0
Nicotinic Acid (mg.)	11	18	20
Vitamin D, I. U.	——	400–800	400–800

*Energy requirements vary with activity, size of the person, etc.
†The requirement for vitamin A may be less if it is provided as vitamin A and may be more if chiefly in the form of carotene.

requirement for each nutrient (i.e., the amount which will just prevent clinical signs and symptoms of deficiency). In advising women in regard to their diets during pregnancy, our aim should be to assure that enough of each nutrient is included in the food actually eaten to provide for the best possible health during pregnancy and in preparation for labor, delivery and the post-partum period, as well as to provide an environment which will permit the optimum growth and development of the fetus. These allowances presuppose that women enter pregnancy in optimum nutritional condition, a supposition which is often far from true. Although the increased requirements up to the fourth month are so small as to be negligible, if the diet has not been good previous to pregnancy it should be improved as soon as pregnancy is recognized. Ideally, women should be taught as a part of their general education that it is important to enter pregnancy in excellent nutritional state. If Warkany's findings in relation to congenital malformations in animals are even in part applicable to man, correcting the diet of the pregnant woman after the first three months would not be effective in preventing congenital malformations if deficient diet is a factor. It is probably true that a woman's long time food habits prior to pregnancy, her diet early in pregnancy and her diet during the latter part of pregnancy all have important, although possibly different, effects on both the mother and fetus."

TABLE III. Foods Providing Required Amount of Nutrients Daily

Milk	40 ounces (2½ pints)
Cheese	1 ounce
Butter	2 ounces
Egg	1 serving
Meat	1 serving (liver once a week)
Whole grain or enriched bread	4 slices
Whole grain or restored cereal	1 serving
Potato	1 serving
Yellow or green leafy vegetables (carrots, string beans, watercress)	1 serving
Orange juice	3 ounces
or	
Tomato juice	7 ounces
or	
Grapefruit juice	4 ounces
Other fruits	1 serving
Vegetable such as cabbage or tomato	1 serving

Conclusion:

In reviewing the present evidence on the importance of diet during pregnancy, Burke and Stuart (25) state:

> "With such strong evidence that good diet during pregnancy lessens the likelihood of complications and contributes to a safer labor and delivery, there would seem to be ample reason for intensive efforts on the part of obstetricians and general practitioners to improve the diets of all pregnant women coming to them for prenatal care. The added evidence that women who have excellent or good diets during pregnancy are much more likely to have healthy well developed infants, and much less likely to have stillborn or prematurely born infants or infants who die in the neonatal period, increases the incentive to improve maternal dietaries."

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